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Dredging Research
Technical Notes

Laboratory Tests of Production Meter Instruments

Purpose

This technical note describes a laboratory test on dredge production meters and discusses some of the test results. The note covers the test equipment, material, and procedures used to evaluate instrument performance under controlled conditions of slurry type, concentration, flow, and pipe orientation. Information is provided that will aid the dredge operator in the selection and use of production meters.

Background

A dredge production meter is a system that determines slurry velocity and slurry density and combines the two values to estimate dredge performance. This estimate of dredge production is a function of the accuracy of the individual meters. There are several types of flowmeters, for example, electromagnetic, doppler acoustic, and differential pressure, each with its own level of accuracy. The same is true of density measuring devices. Therefore, under identical conditions, a production calculation using doppler flowmeter and nuclear density gage values may be very different from calculations made using a bend flowmeter and pressure transducer specific gravity U loop values.

Production Meter Technology is a work unit designed to evaluate production meter performance with the aim of determining meter accuracy and ranges of best performance. This note summarizes laboratory results which can be used in the selection of production meter equipment for a variety of dredging operations.

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Additional Information or Questions

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Introduction

Georgia Iron Works, Inc. (GIW), a pump design and fabrication company, operates a research facility where their pumps are tested and evaluated. Part of this facility includes a closed test loop in which slurry flow and concentration can be monitored, controlled, and measured. Under a Dredging Research Program (DRP) contract, this loop was used to evaluate the performance of several flow and density meters for a number of conditions.

Facility meters, which were used as controls, were calibrated according to procedures established at GIW, which uses an American Society for Testing and Materials standard orifice plate. Table 1 identifies the facility control and back-up meters and the seven test meters. All test meters were installed and calibrated according to manufacturers' procedures by their factory technicians. Once the tests were started no adjustments were made to any of the meters.

Table 1

Control and Test Instruments

Flowmeters
Control - Fischer & Porter magnetic flowmeter
Backup - Bend velocity meter
Test Instruments
Doppler flowmeters
Texas Nuclear--dual sensors
Polysonics--single sensor
Leeds & Northrup--single sensor
Magnetic flowmeters
Rosemount
Brooks
Density Gages
Control - Specific Gravity U loop with Rosemount pressure transducers
(Continued)

Table 1 (Concluded)

Backup - Texas Nuclear densitometer	
Test Instruments	
	<u>Nuclear Density Gage</u>
	Texas Nuclear
	Kay-Ray

Materials and Methods

A series of tests was run with four different grain size materials each at three different concentrations (20, 30, and 40 percent concentration by weight) through a flow range from 0 to 4,000 gpm (0-26 ft/sec). The test instruments were mounted on a U-shaped section of pipe that could be raised 90 deg from a horizontal to a vertical orientation. The diameter of the pipe used for these tests was 8 in. Data for the control and test meters were taken at 12 to 15 points along the flow range with the meters in both the vertical and the horizontal pipe position. The location of the test meters on this special section of pipe along with a glass observation section is illustrated in Figure 1. The control flow and density meters were located approximately

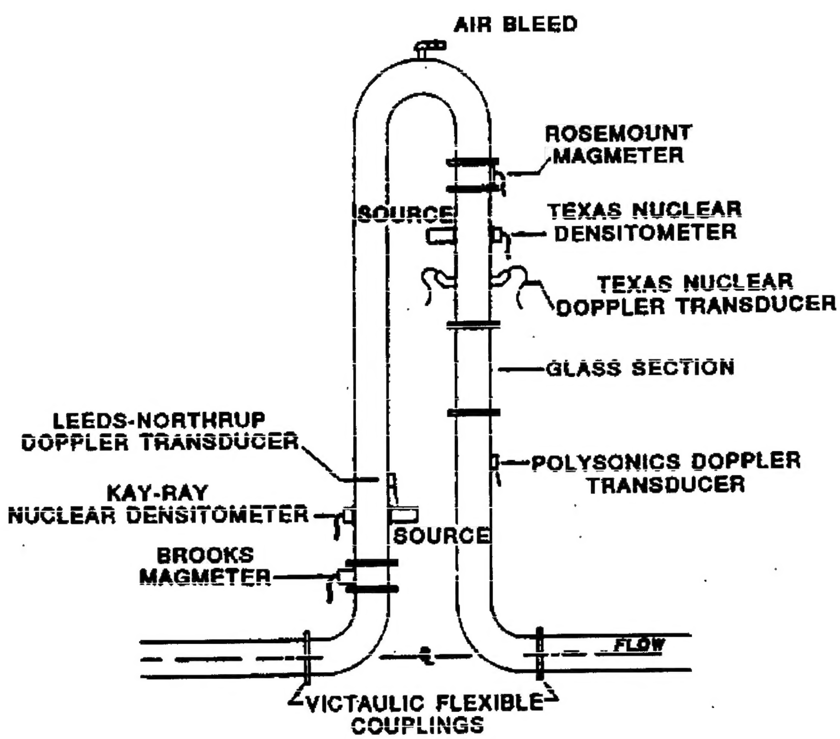

Figure 1. Layout of instrumentation loop

330 ft upstream from the test instruments. Table 2 lists the test conditions. Before each new material was added, data were collected through a range of velocities with only water in the test loop.

Table 2

Test Conditions

Material Types	
Gravel	D_{50} = 16-19 mm
Plaster sand	D_{50} = 0.70 mm
Foundry sand	D_{50} = 0.30 mm
Sand washings	D_{50} = 0.06 mm
Slurry Velocity Range	
0 - 26 ft/sec (0 - 4,000 gpm)	
Slurry Concentrations	
Specific Gravity (SG) 1.1 - 1.3	
Concentration by weight (Cw) 15 - 40%	
Test Loop Orientation	
Vertical	
Horizontal	

Results and Discussion

This study indicates that for determining dredge production, the most reliable instruments for measuring slurry flow and density are the magnetic flowmeter and the nuclear density gage. Their accuracy is enhanced if they are mounted on a vertical pipe section.

The recorded flow and density values from the test instruments were compared to the control meters and each other to determine the range of readings among the instruments for a given flow and density. The relationship between the control and the test instrument values can be expressed as percent difference using:

$$Q_d = \frac{Q_{test} - Q_{cont}}{Q_{cont}} \times 100$$

$$SM_d = \frac{SM_{test} - SM_{cont}}{SM_{cont}} \times 100$$

where Q = flow
SM = slurry mixture specific gravity
subscripts d, test, and cont = difference, test, and control instrument values, respectively.

Expressing the percent difference of the control instrument from the test instrument will give a $+Q_d$ for test instrument values greater than the control instrument and a $-Q_d$ for test instrument values less than the control instrument.

With sand slurries, the nuclear density gages had values within 1 percent of each other: for gravel this increased to almost 5 percent. The magnetic flowmeter values were within 4.7 percent of each other for sand slurries and 5.7 percent for gravel. Both performed better when mounted on the vertically oriented pipe section. The data for the doppler flowmeters shows similar trends and, although each meter is fairly self consistent, there are distinct differences among the three test doppler meter values. The doppler meters show greater differences from the control meter than did the magnetic flowmeters in all cases. The dual sensor doppler flowmeter had a larger percent difference than either of the single sensor doppler meters. This meter had consistently higher values throughout the tests, which could indicate improper calibration. However, it was the test procedure to leave unchanged the instrument calibrations which were performed by a company representative.

Table 3 shows the largest percent difference values obtained for density and flow for the range of concentrations and material types tested in both the vertical (90 deg) and horizontal (0 deg) pipe orientations.

Table 3

Largest Percent Difference for All Slurry Concentrations

	Percent Difference							
	Plaster Sand		Foundry Sand		Sand Washings		Gravel	
	Pipe Orientation deg		Pipe Orientation deg		Pipe Orientation deg		Pipe Orientation deg	
	90	0	90	0	90	0	90	0
Nuclear Density Gage								
Texas Nuclear	-0.1	-0.7	0.0	2.2	0.5	-1.0	4.0	5.0
Kay-Ray	-0.1	-2.0	-1.0	2.2	0.7	0.5	-0.7	7.5
Magnetic Flowmeters								
Brooks	-0.1	2.5	0.5	-3.7	-2.1	1.0	0.0	5.0
Rosemount	-1.0	5.0	-1.5	1.0	3.5	-1.5	-2.0	-0.7
Doppler Flowmeters								
Leeds & Northrup	-7.0	-6.0	0.0	7.0	-5.0	-5.0	20.0	17.0
Texas Nuclear	20.0	30.0	25.0	20.0	15.0	15.0	15.0	50.0
Polysonics	-15.0	-15.0	-15.0	-7.0	-10.0	-15.0	-12.0	-7.5

The meters were influenced by material type in that the gravel data presented the greatest percent difference for both the flow and density gages. Slurry flow had no significant effect on the magnetic flowmeters or the nuclear density gages, but did affect the doppler flowmeter values. The differences between the control meter values and the test doppler values increased with increasing slurry flow. At a control meter flow of 1,000 gpm (6.5 ft/sec), the doppler meter values were from 0.5 to 28 percent higher than the control meter, and at a flow of 4,000 gpm (25.6 ft/sec), values were from 22 percent lower to 16 percent higher. This trend is observed with the doppler instruments in both the vertical and the horizontal orientation. Even without sediment, the doppler flowmeters tended to record less than the control flowmeter at high flows.

Slurry concentration appears to have a minor influence on the meter values in all but one condition. In general, the percent difference increased slightly with the increase in slurry concentration. However, at high slurry concentration, low flow, and horizontal pipe orientation, material settles on the bottom of the pipe and moves as a sliding bed with higher velocity, less dense, fluid moving above it. This condition is conducive to dune formation and movement, which was observed. With this condition present, erroneous or erratic values could be recorded.

This study emphasizes that caution should be used in the selection of a production meter, especially the flowmeter component. Ideally a magnetic flowmeter should be used, giving careful consideration to such factors as accuracy, initial cost, and maintenance requirements. The easiest flowmeter to install and the least expensive to purchase is the doppler type flowmeter. However, this type of meter showed more variation in the data and differed most from the control meter. The data spread among the three doppler meters was much greater than the data spread between the two magnetic flowmeters.

The nuclear density gage is the only readily available densitometer used on contemporary dredges. It is reliable, accurate, and safe to use. However, it does employ a radioactive source and therefore a Nuclear Regulatory Commission (NRC) license is required. Many dredge operators prefer not to use this type of gage because of the required licensing and training.

Conclusions

General conclusions that can be made from these tests are as follows:

1. The most accurate flowmeters tested were, in decreasing order, magnetic and doppler.

2. The density gages had almost identical readings with each other and the control density meter.

3. The magnetic flowmeters had very similar readings with each other and the control flowmeter.

4. The doppler flowmeters had significantly different readings from each other and the control flowmeter.

5. The preferred pipe orientation for both density gage and flowmeter is vertical, but a horizontal pipe is acceptable if high slurry concentrations that produce a stationary or sliding bed with dune formation are avoided. The difference between vertical and horizontal orientation is on the order of 1 percent for the density gage, 3 percent for the magnetic flowmeters, and 5 percent for the doppler flowmeters.

6. Sand slurry flow results were more consistent and accurate than those for gravel.

7. The doppler meters produced higher values than the control meter at low slurry velocities and fell off significantly, producing much lower values than the control, at higher slurry velocities.

Dredge production meter values can be used as an aid in optimizing dredge operation and production. All flowmeters tested were acceptable and indeed are preferable to no meter at all. The meters were consistent throughout the test and responded to changes in slurry concentrations, flow, and material types. The most critical element in the use of production meters is the calibration of the individual components.

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